BIOTECHNOLOGY LABORATORY

PROGRESS REPORT

June 15, 1961

ARM PROSTHESIS RESEARCH
(Contract V1005M-2075 with U. S. Veterans Administration)

OBSERVER PRACTICE
(Contract Nonr-233(49) with U. S. Office of Naval Research)

HUMAN THERMAL STUDIES
(Contract AF33(616)-6763 with U. S. Air Force)

HUMAN TRACKING
(Contract N123 (60530)23558A with U. S. Naval Ordnance)

Project Leader: John Lyman
Associate Professor of
Engineering and Psychology

REPORT PREPARED BY
LABORATORY STAFF

Engineering Dept. Report No. 61-49

DEPARTMENT OF ENGINEERING
University of California
Los Angeles

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FOREWORD

The research described in this report, *Biotechnology Laboratory Progress Report*, by the Laboratory Staff, was carried out under the technical direction of John Lyman and is part of the continuing program in Arm Prosthesis Research, Observer Practice, Human Thermal Studies, and Human Tracking.

The Biotechnology Laboratory is part of the Department of Engineering of the University of California, Los Angeles; Dean L.M.K. Boelter is Chairman of the Department of Engineering and Professor J. M. English acts as his representative for research activities.

J. M. English
Vice Chairman - Research

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Sponsor: U. S. Veterans Administration

A. Electromyographic Studies

1. Equipment Modifications and Developments

a. Binary Myoelectric Feedback

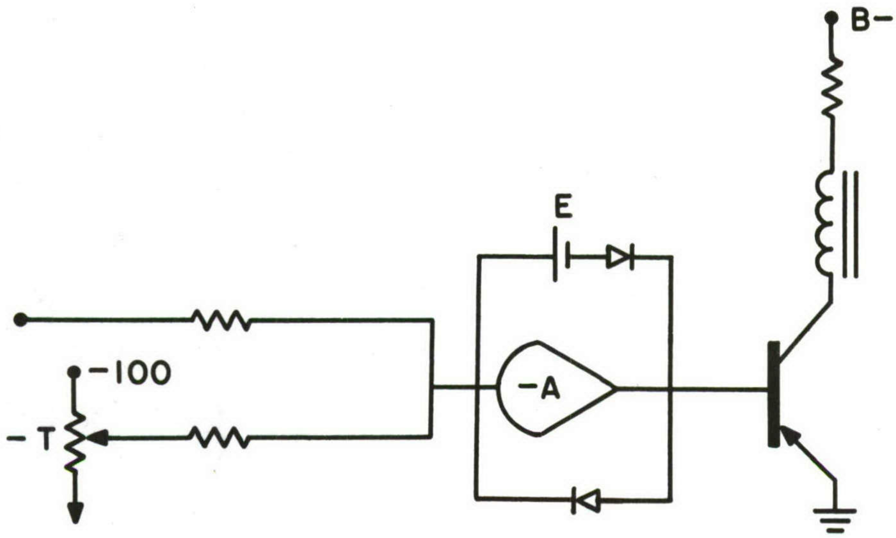
Utilization of visual or tactile feedback as training aid for the voluntary elicitation of specific myoelectric activity patterns has been discussed in previous progress reports. In accordance with earlier findings as to "natural" signal-to-noise ratios, it was decided to initially supply this feedback on a binary basis, i. e., the subject is to be informed simply whether a muscle is active or inactive. For any particular muscle site, the Active/Inactive threshold is a level chosen by the experimenter; thus by proper assignment of these levels it should be possible to force the subject -- if he succeeds in achieving the assigned pattern -- to demonstrate a given set of signal-to-noise ratios. Starting with relatively low ratios, the experimentator can gradually train the subject to perform better.

The feedback equipment must have the following properties in order to permit this mode of experimentation:

1. The feedback channels must be individually controllable.
2. The threshold level control must be readily available.
3. The binary signal must be unambiguous, and must respond rapidly to changes in myoelectric activity.

A myoelectric discriminator circuit having these properties has been adapted to the laboratory's analog computer, thus providing both flexibility in use and the potential of readily adding additional channels. One discrimination channel is shown in Figure 1.

The myoelectric signal is first subjected to the smoothing transformation described in other reports, and then compared with a reference voltage level T



MYOELECTRIC SIGNAL DISCRIMINATOR CIRCUIT

FIGURE 1

at the grid of an operational amplifier. When the smoothed signal exceeds T volts, the grid goes positive, hence the output is driven negative, the diode in the upper path conducts and the output voltage is clamped at E volts. For myoelectric signals below T volts, the lower diode conducts, starting the amplifier, and keeping its output at zero. The amplifier output is exactly suited to drive the base of a PNP transistor which activates the coil of a relay when the muscle under consideration is nominally "active". Any binary feedback device may be attached to the relay contacts. The threshold level is readily available through a potentiometer setting; the amplifier output voltage is effectively independent of the amount the signal exceeds threshold; thus the turn-on condition for the transistor is stable. Millisec relays assure a reaction time short enough so that no lag is noted.

Preliminary results of the muscle isolation study (Section 2b) indicate that sensory feedback is as important as was postulated; thus it appears that even a binary feedback device should greatly enhance training.

b. Elimination of EKG Signal

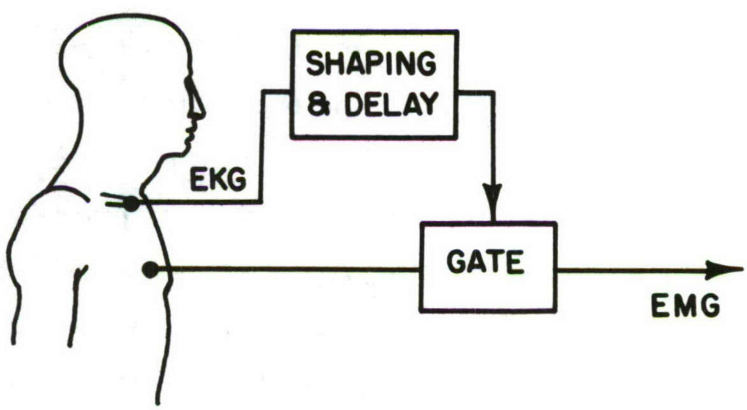
Because of the relatively high amplitude EKG signal superimposed on the myoelectric signal at most chest and back sites, usefulness of these sites for prosthesis control is questionable. In particular, the pectoralis signals are effectively masked when standard transformations, as for example, rectification and smoothing, and repetitive integrations are applied. Current evidence suggests, however, that pectoralis contractions can be readily isolated by training and, if the EKG interference were eliminated, would yield a good signal-to-noise ratio. Hence an intensified effort to discover a means for elimination of EKG interference has been initiated.

Simple filtering of the EKG signal will not provide the desired results, since the frequency band of the EKG signal overlaps much of the EMG signal's band, and information as well as noise would be eliminated. The most fruitful approach appears to be use of the EKG signal to eliminate itself. This might be accomplished in two ways:

(1) Obtain a clear EKG signal at a point near the heart; invert it, and sum with the signal obtained at the muscle site: EKG activity will cancel, leaving only EMG signal.

(2) Obtain a clear EKG signal at a point near the heart; use it as a gate control to block all signals from a muscle site, thus eliminating both EKG and EMG for a short period.

Of the two possibilities, the second seems the better approach. Cancellation by inversion can be expected to be less satisfactory than complete blocking due to such factors as EKG propagation time and attenuation in the body. If the site EKG signal is not exactly cancelled, the inverted control spikes become a new noise source. A proposed gating scheme is shown schematically in Figure 2.

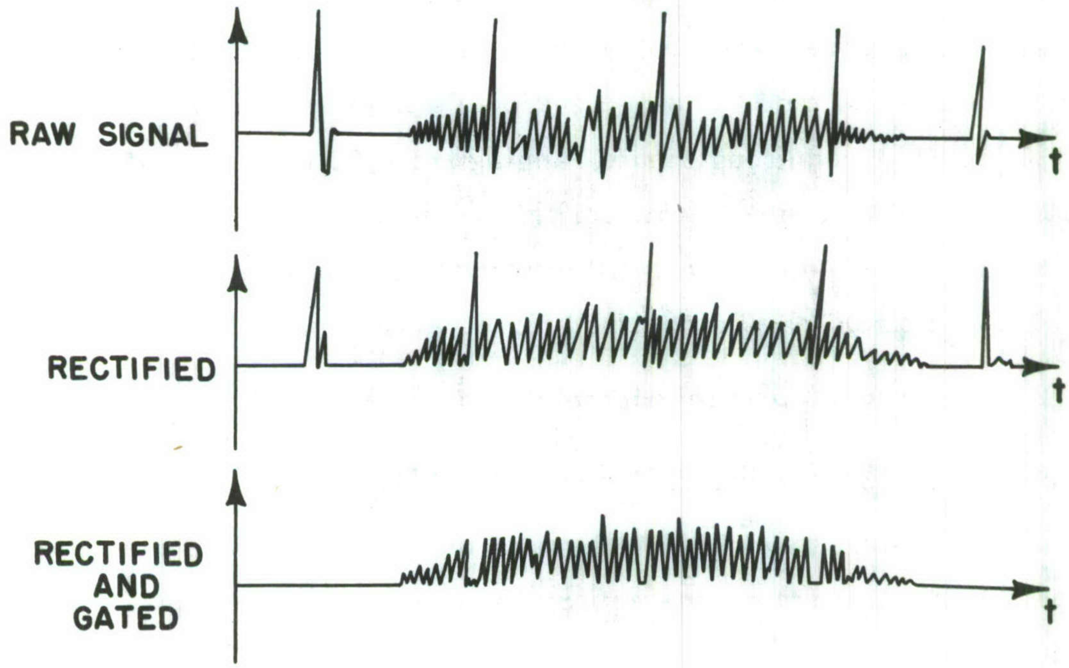


PROPOSED EKG ELIMINATION

FIGURE 2

The control signal is preferably obtained from a body location which is relatively free of muscular activity yet is closer to the heart than any postulated control sites. The middle back, the sternum, and the regions directly over the clavicles would be potentially good control sites. As the gate is assumed closed during the entire presence of the control EKG pulse, the trailing edge of this pulse might be suitably delayed to allow for propagation time to the muscle site.

The resultant myoelectric signal would have gaps occurring at a frequency equal to the heart rate. The relation of untransformed to transformed signal is illustrated in Figure 3.



POSTULATED MUSCLE-SITE SIGNALS

FIGURE 3

During periods of inactivity, these gaps would, of course, have no effect. When myoelectric control is desired, they could contribute considerable delay at initiation and periodic halts during operation. It is not yet certain how wide the gaps will have to be made. If they are relatively narrow, subsequent capacitive smoothing may minimize their adverse effects; if they are wide, a control "memory" may be provided to bridge the periods of inactivity.

No fundamental difficulties are expected in the implementation of such a gating circuit. The primary investigative variables will be optimum placement of the control electrodes, minimum gap possible, and the probable subsequent effects of the gaps on control. Study of this transformation is planned for the next quarter.

c. <u>New Developments</u>

Two potentially useful developments are a transistorized, sensitive relay and a sensitive meter relay, both to be available in a few weeks. These assemblies are claimed by their developers to provide power gains ranging from 10^6 to 10^9, requiring inputs ranging from 50 to 500 manowatts to control outputs as great as one kilowatt. Their response times are short enough to permit use in a pulsed servo-system providing proportional control, and special assemblies may be obtained for direct coupling to myoelectric signals.

2. Functional Dissociation of Muscle Activity

a. <u>Critical Evaluation of Training Techniques</u>

Cooperation of Dr. Walters of the UCLA Medical School enabled us to repeat in his laboratory the experiments of "sensory stimulation" to elicit muscle contraction.

The area of the C-6 dermatome was brushed at the rate of about 5 strokes per second and biceps activity was recorded with coaxial needle electrodes. Artifacts similar to those obtained in our own laboratory became apparent again and an evaluation of the new records as to the cause of these "activity patterns" is in progress. However, it was possible to establish beyond

reasonable doubt that the recorded activity did not correspond to neural activity of the muscle.

Since none of the subjects ever became consciously aware of the expected muscle contraction, we feel that this method will be unsuitable as a training technique.

b. Studies of Voluntary Muscular Control

Studies of muscle activity in athletes who possess voluntary control over selected muscle groups are nearly completed. On seven out of twelve subjects continuous photographic and EMG recordings have been obtained. A summary of the observations to date is illustrated in Figure 4.

A 5 x 5 cm grid has been stamped on the muscle and motion pictures have been taken at the rate of 16 frames per second during contraction. The method is illustrated in Figure 5.

Although the records give an excellent visual indication of the point of maximum deformation as well as of the direction in which the bulge travels, a quantitative analysis of the data seems virtually impossible. Since three-dimensional data have been projected on a two-dimensional surface and because of the lack of a reliable system of reference coordinates, all attempts to reduce the obtained data have been unsuccessful so far.

Furthermore, we feel that the problem of variability of skin elasticity between individuals and also in different body areas would always limit any objective solutions to the quantitative analysis of these records.

A literature study was conducted to obtain data of the elasticity of the skin and subcutaneous tissues and to establish a relationship between skin elasticity and skin deformations due to muscle contraction.

The primary difficulty in obtaining a consistent listing of the elastic moduli of the skin and subcutaneous tissues is that of isolating the system for study without altering it and introducing artifacts.

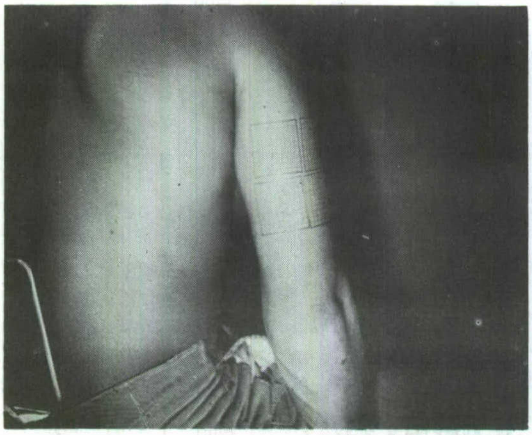
SUBJECT / MUSCLE	1		2		3		4		5		6		7	
	L	R	L	R	L	R	L	R	L	R	L	R	L	R
PECTORALIS		●●		●●	●	●		●	●	●			●	●
TRICEPS			●●	●●		●		●	●●	●		●		○
BICEPS		●											●	●
TERES		●●●			●	●						○		
DELTOID						○		○		○		○		○
LATISSIMUS								○				●●		
ABDOMINALS							●	●						

● ACTIVELY ISOLATED

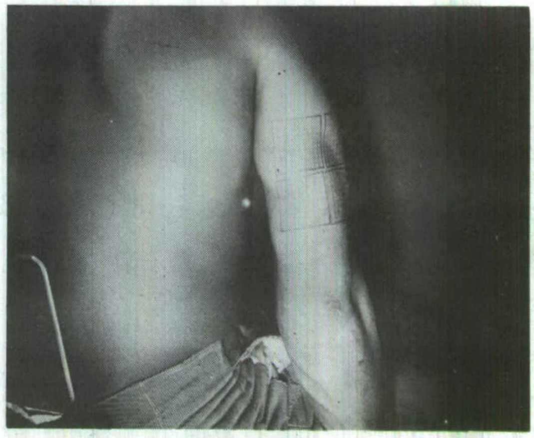
○ ONLY INSTRUMENTED

OBSERVATIONS OF VOLUNTARY MUSCLE CONTROL
IN SEVEN ATHLETES

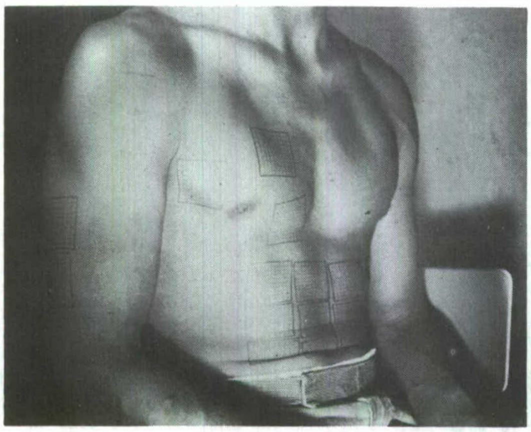
FIGURE 4



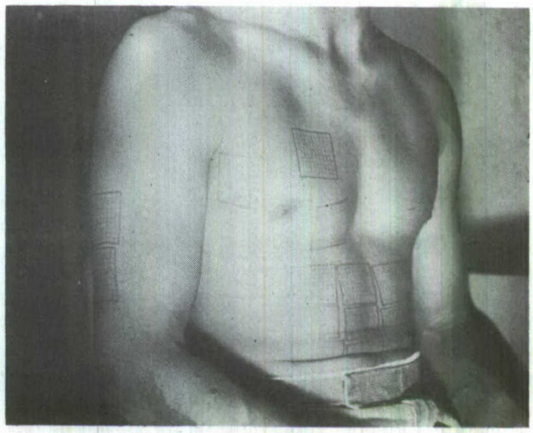
REST RIGHT TRICEP



TENSE RIGHT TRICEP



TENSE RIGHT PECTORAL



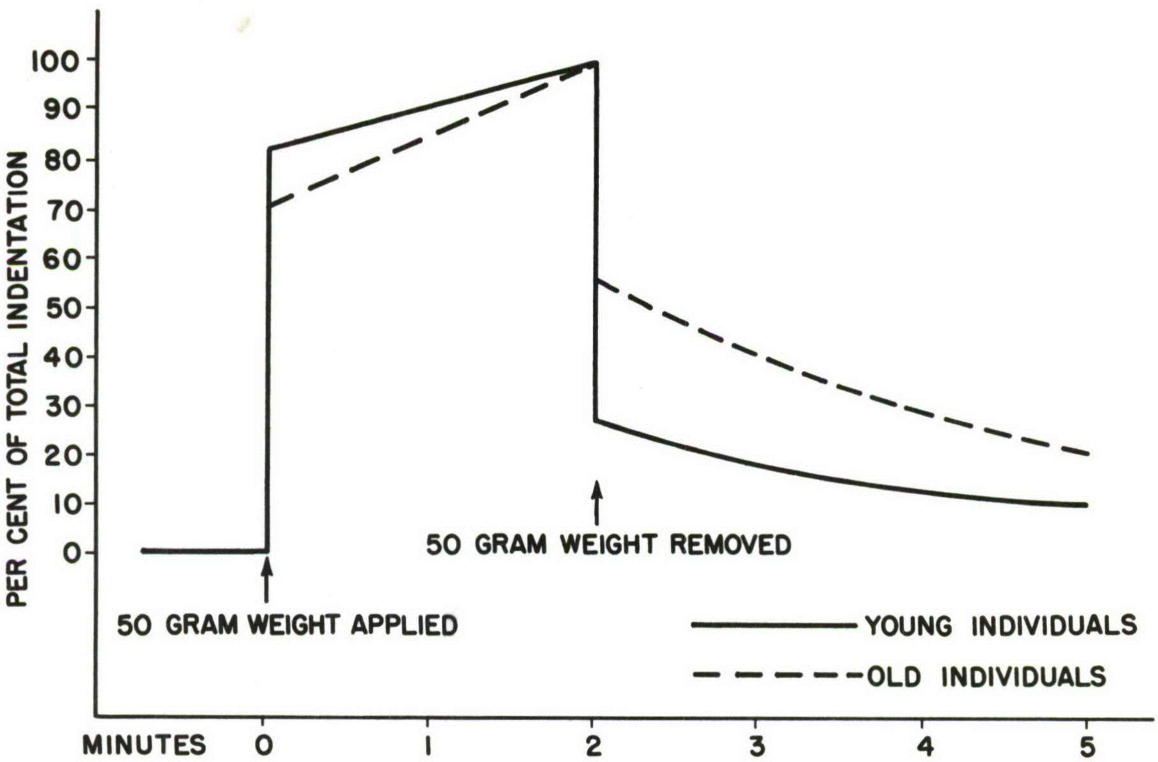
REST RIGHT PECTORAL

PHOTOGRAPHIC RECORDINGS OF MUSCLE BULGE DURING CONTRACTION

FIGURE 5

Specific methodology permits achievement of a certain amount of statistical homogeneity and makes it possible to make some fairly reliable statements about the elasticity of the skin during deformation.

A series of investigations by Kirk and Kvorning (1949) to determine the elastic properties of the skin and subcutaneous tissue of young and old people showed a marked difference between the two age groups. An indentation following the application of a weight on the skin, was greater in 24 young individuals (age 18 to 25 years) than in 28 older individuals (60 to 86 years), and the immediate rebound of the tissue after removal of the weight was greater in the young group than in the old group. The results are illustrated in Figure 6.



COMPARISON OF ADAPTATION AND RESILIENCE OF SKIN AND SUBCUTANEOUS TISSUE OF YOUNG AND OLD INDIVIDUALS

(Kirk and Kvorning[2])

FIGURE 6

As may be seen from the graph of Kirk and Kvorning's results, there is a slow flow of skin under stress. In addition to this, an inspection of their data shows that in the young group, the parameters used for measuring skin elasticity varied extensively between individuals. The greatest variation was found in the primary rebound in percent of total indentation where individual variations were on the order of from 5% to 200%. Similarly, though less marked, individual variation is found in the older groups. The original data are presented in Tables 1 and 2.

Olmsted, Page, and Corcoran (1951) have devised an instrument which measures a skin elasticity coefficient on a principle similar to digital punching. The slow flow of skin described earlier does not interfere with measurements by this briefer procedure. Values of elasticity coefficient differ for different sites and different age groups. These values may then be compared to normal values at various sites for different age groups. Skin elasticity is scored in multiples of normal values. The ratio rarely exceeds eight (Olmstead, Page and Corcoran, 1951).

Both Kirk and Kvorning's investigations and Olmsted, Page and Corcoran's studies indicate that utilizing skin and subcutaneous elasticity for reducing the obtained muscle bulge records is highly impractical even though an interrelationship between the elasticity and the bulge does exist.

Preliminary results of the electromyographic studies on the seven athletes during contraction of selected muscle groups in terms of signal-to-noise ratios are shown in Tables 3, 4 and 5.

c. <u>Electrical Stimulation of Muscle</u>

Electrical stimulation of the muscle to be trained as a control site presently appears to be the most promising training method. A commercially available stimulator (Trade name: RelaxAcizor) is expected to provide a convenient and safe method for eliciting controlled contraction in any desired muscle.

TABLE 1

MEASUREMENTS OF ELASTIC PROPERTIES OF THE SKIN AND SUBCUTANEOUS TISSUE OVER LOWER ASPECT OF THE TIBIA IN 24 YOUNG INDIVIDUALS

			First Period				Second Period				Third Period			
No.	Sex	Age	Total Inden- tation in mm.	Primary Indentation in % of Total Indentation	Primary Rebound in % of Total Indentation	Total Rebound in % of Total Indentation	Total Inden- tation in mm.	Primary Indentation in % of Total Indentation	Primary Rebound in % of Total Indentation	Total Rebound in % of Total Indentation	Total Inden- tation in mm.	Primary Indentation in % of Total Indentation	Primary Rebound in % of Total Indentation	Total Rebound in % of Total Indentation
1	M	18	3.9	77	75	100	3.6	83	81	100	3.6	86	83	100
2	M	18	4.2	91	76	100	4.2	62	83	98	4.2	88	79	100
3	M	19	3.9	85	84	92	3.6	89	84	92	3.7	86	81	97
4	M	19	3.7	81	89	100	3.7	87	87	97	3.8	89	74	97
5	M	19	2.1	91	62	100	2.2	87	59	96	2.1	86	62	105
6	M	19	1.9	74	89	106	2.3	87	57	96	2.3	87	57	96
7	F	19	3.1	74	58	84	2.8	82	68	93	2.6	89	73	96
8	M	20	3.8	87	76	76	3.3	85	73	94	3.3	85	67	85
9	F	20	4.9	92	96	104	5.0	86	88	98	5.1	84	86	92
10	F	20	4.0	78	87	98	4.2	76	86	93	3.5	89	86	98
11	M	20	3.1	84	78	93	3.1	81	78	97	3.0	80	93	104
12	M	20	1.8	67	50	61	1.6	75	62	100	1.6	75	69	88
13	M	20	2.4	87	87	103	2.6	96	77	100	2.7	89	78	97
14	M	20	2.5	72	48	76	2.4	88	54	83	2.8	86	54	93
15	F	20	4.8	79	75	92	4.4	82	82	100	4.5	78	78	96
16	F	21	4.8	88	88	100	4.6	87	87	100	4.8	90	83	100
17	F	22	4.3	86	91	93	4.4	82	81	102	4.1	93	98	103
18	M	22	3.9	82	82	97	4.1	86	90	97	4.7	83	81	96
19	M	22	2.7	81	70	89	2.6	89	77	100	2.7	89	74	96
20	F	22	3.8	84	92	95	3.7	87	95	100	3.6	86	89	100
21	F	23	5.5	71	80	84	4.5	89	80	96	4.4	87	91	102
22	M	24	1.9	84	84	100	1.9	90	74	105	1.4	---	---	----
23	M	24	3.5	83	66	88	3.3	82	67	98	3.2	88	72	97
24	M	25	2.1	81	33	67	1.5	80	47	93	1.4	86	50	107
Mean			3.4	82	76	92	3.3	84	76	97	3.3	86	77	94

TABLE 2

MEASUREMENTS OF ELASTIC PROPERTIES OF THE SKIN AND SUBCUTANEOUS TISSUE OVER LOWER ASPECT OF THE TIBIA IN 28 ELDERLY INDIVIDUALS (MEASUREMENTS PERFORMED IN THE MORNING)

			First Period				Second Period				Third Period			
No.	Sex	Age	Total Inden- tation in mm.	Primary Indentation in % of Total Indentation	Primary Rebound in % of Total Indentation	Total Rebound in % of Total Indentation	Total Inden- tation in mm.	Primary Indentation in % of Total Indentation	Primary Rebound in % of Total Indentation	Total Rebound in % of Total Indentation	Total Inden- tation in mm.	Primary Indentation in % of Total Indentation	Primary Rebound in % of Total Indentation	Total Rebound in % of Total Indentation
25	M	60	2.4	75	42	88	2.0	90	50	120	2.7	82	67	93
26	M	63	1.5	67	41	74	1.2	75	50	100	1.1	82	46	100
27	F	64	3.0	70	44	77	2.4	79	50	96	2.6	82	43	89
28	M	65	1.3	54	39	69	1.7	64	45	82	1.0	80	40	90
29	M	65	3.1	78	53	94	2.8	75	58	93	2.7	85	63	96
30	M	65	3.7	76	66	95	3.5	83	69	97	3.5	85	68	97
32	M	66	3.4	86	38	91	3.1	94	45	97	3.3	91	40	97
33	M	66	3.9	67	41	74	3.0	80	57	97	2.9	86	52	93
34	F	66	3.5	80	66	89	3.0	73	60	87	—	—	—	—
35	M	67	2.8	57	61	75	2.3	74	52	91	2.2	82	55	64
36	M	67	2.7	51	38	71	2.2	73	46	87	2.1	76	43	91
37	M	68	2.6	77	43	85	2.5	83	44	92	2.5	84	60	96
38	F	69	1.5	74	40	80	1.4	72	28	79	1.2	75	42	92
39	M	70	1.3	69	23	54	0.9	78	33	78	0.8	75	38	88
40	M	71	2.5	68	36	88	2.2	87	41	82	1.8	89	62	105
41	M	71	2.1	76	33	76	1.6	81	44	—	—	—	—	—
42	M	72	4.3	75	42	79	3.9	83	41	95	3.8	76	47	97
43	M	74	2.6	69	42	77	2.0	80	50	120	2.0	75	50	85
44	M	74	3.4	62	53	91	3.1	75	65	97	3.0	74	40	94
45	F	76	3.1	71	48	84	2.7	89	52	89	2.5	89	48	88
46	M	77	2.3	74	57	87	1.9	79	63	100	1.8	78	73	100
47	M	77	2.4	71	52	88	—	—	—	—	2.0	85	45	100
48	M	80	1.5	74	34	74	—	—	—	—	1.2	75	42	84
49	M	81	1.1	64	27	73	0.9	67	67	89	0.9	56	33	100
50	M	81	1.7	71	35	88	1.7	65	35	94	1.5	80	40	100
51	M	81	2.5	68	45	84	2.2	77	50	91	2.0	85	50	95
52	F	82	5.7	79	40	79	4.9	82	45	100	6.0	80	38	87
53	M	86	3.1	59	41	69	2.3	69	50	85	2.1	58	29	74
Mean			2.7	70	43	81	2.3	77	49	93	2.3	74	48	92

TABLE 3

SIGNAL-TO-NOISE RATIOS FOR CONTRACTION OF RIGHT PECTORALIS

Subject	Right Pect. / Rt. Tric.	Rt. Pect. / Rt. Delt.	Rt. Pect. / Lt. Pect.
#5	3/1	4/1	2/1
#4	4/1	3/1	2/1
#3	2/1	1/1	-----*
#2	1/1	-----*	-----*

Order of Magnitude Signal From Right Pectoralis = 120μ volts

*No data taken.

TABLE 4

SIGNAL-TO-NOISE RATIOS FOR CONTRACTION OF RIGHT TRICEPS

Subject	Rt. Tric. / Rt. Delt.	Rt. Tric. / Rt. Pect.
#5	4/1	2/1
#4	3/1	5/1
#3	1/1	2/1

Order of Magnitude Signal From Right Triceps = 200μ volts

TABLE 5

SIGNAL-TO-NOISE RATIOS FOR CONTRACTIONS OF RIGHT LATISSIMUS

	Latissimus / Right Teres	Latissimus / Right Triceps	Latissimus / Right Biceps
Subject 6	$\frac{1.5}{1}$	$\frac{1.5}{1}$	$\frac{1.5}{1}$

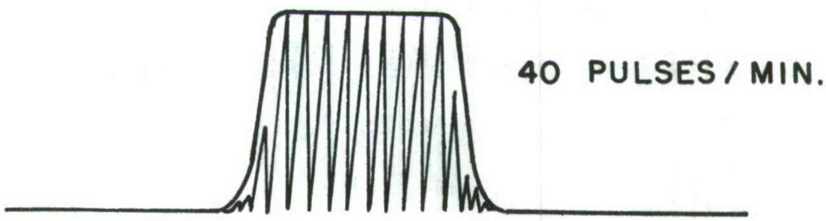
Order Of Magnitude Signal From Right Latissimus = 50μ volts

These forced contractions will provide the amputee with the necessary proprioceptive feedback or "feel" in order to gain voluntary control over the selected control site.

Demonstration of the RelaxAcizor indicated its potential usefulness as a training aid and an order has been placed for acquistition of a unit modified for our requirements.

Although requested technical information has not been received to date, a laboratory check indicated that the unit appears to be a relatively fast pulse generator being gated at 40 pulses/min. The output voltage was observed to be variable from zero to about 70 volts peak-to-peak and apparently capable of going higher.

The observed waveform was approximately as illustrated:



Muscle contraction is elicited by placement of small flexible electrodes on the skin area overlying the motor nerve which innervates the specific muscle. During the demonstration, good local muscle contractions were obtained in the upper trunk regions and the accompanying sensations were quite pronounced.

d. Surgical Isolation of Muscle Activity

This phase of the program remained inactive during the past quarter.

Plans for Next Quarter

1. Completion of the evaluation of existing training methods for functional isolation of muscle activity. Preparation of a report.

2. Completion of the investigation of functional dissociation of muscle activity in athletes. Preparation of a technical note.

3. Evaluation of electrical stimulation of selected muscles in amputees as a training aid to achieve functional isolation.

4. Use of binary display-feedback apparatus as training aid in muscle function isolation in a group of selected amputees.

5. Construction of gating circuitry and evaluation of gating means for eliminating EKG signals from EMG records.

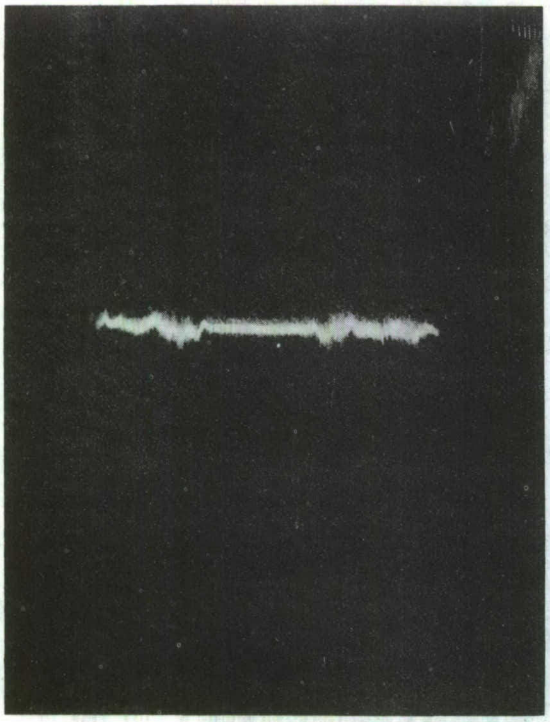
6. Exploration of further methods for quantification of photographic muscle bulge records.

B. Surgical Nerve Replants

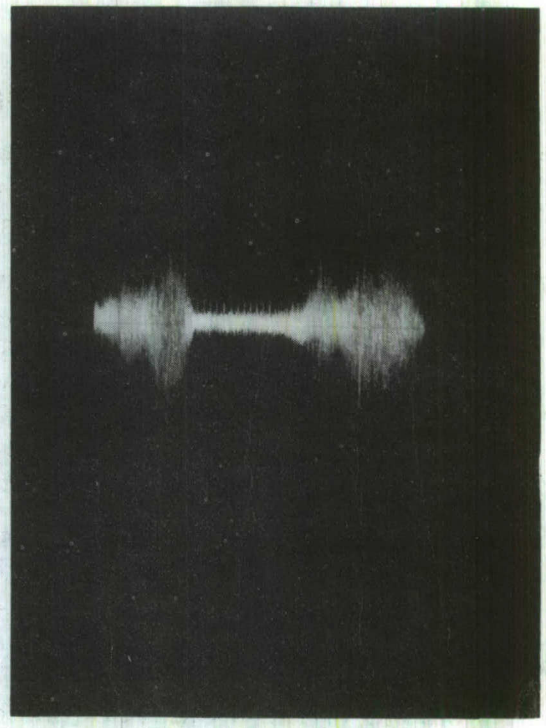
A good sequence of EMG records has been obtained on the Cyne Malagus which strongly suggests good re-innervation of the pectoralis. Signal amplitude of the re-innervated site was found to be higher than of the intact pectoralis. A sample record is shown in Figure 7.

Plans for Next Quarter

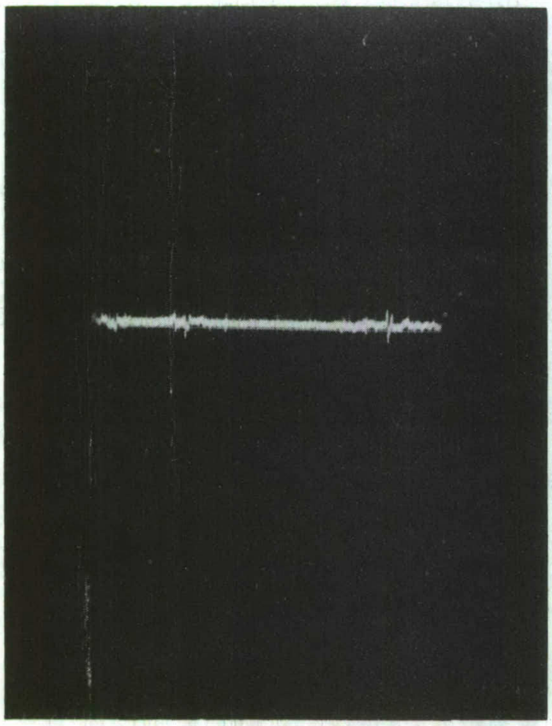
Upon recommendation of Professor Sperry at the California Institute of Technology, EMG measurements of the re-innervated and the intact pectoralis muscles will be made under specified conditions of muscle loadings. An empirical curve will be constructed for both muscles showing EMG amplitude as a function of load. It is expected that an earlier saturation point will be obtained for the re-innervated muscle.



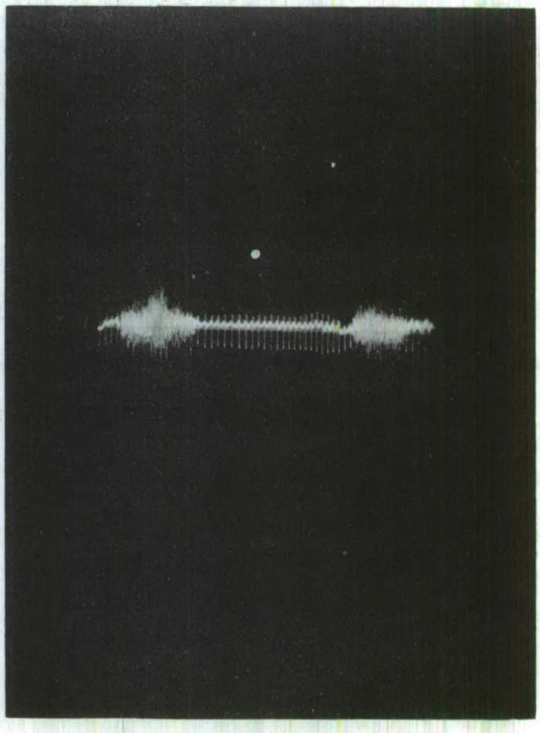
RIGHT BICEPS



RIGHT PECTORALIS
RE-INNERVATED MUSCLE



LEFT BICEPS



LEFT PECTORALIS
INTACT MUSCLE

EMG RECORDINGS OF OPERATED AND INTACT MUSCLES
IN A CYNE MALAGUS

FIGURE 7

REFERENCES

1. Stacy, Williams, Worden and McMorris, Essentials of Biological and Medical Physics, McGraw-Hill Inc., 1955.

2. Kirk and Kvorning, Washington University School of Medicine, " Quantitative Measurements of the Elastic Properties of Skin and Subcutaneous Tissue in Young and Old Individuals", Journal of Gerontology, Ann Arbor, 1949 4/4 (273-281).

3. Olmsted, Page, Corcoran, " A Device for Objective Clinical Measurements of Cutaneous Elasticity: a 'Pinchmeter'", American Journal of the Medical Sciences, 1951, 222 1, (73-75).

II. ENGINEERING ANALYSIS OF BIOTECHNICAL FACTORS IN CONTROL SYSTEMS

Sponsor: U. S. Veterans Administration

A. Kinetic and Kinematic Analysis of Prosthesis Control Motions

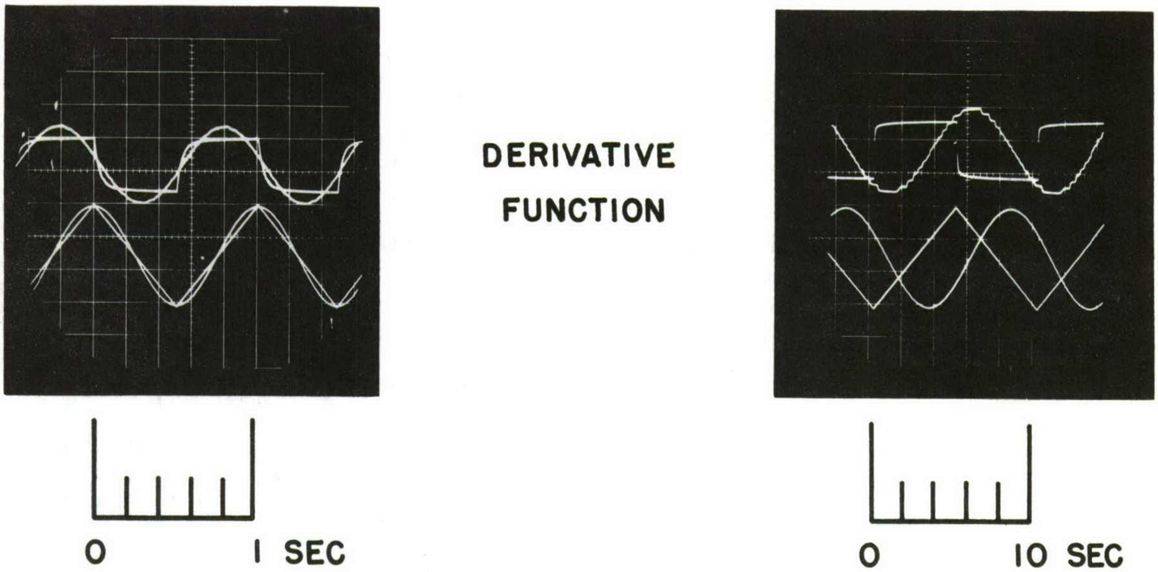
1. Kinesiology of Elbow Flexion

If sufficient help becomes available, the Biotechnology Laboratory elbow dynamometer will be modified during the summer to provide the controlled velocity required for the torque-velocity tests mentioned in the March 1961 progress report. As will be recalled from the December 1960 report, an exponential muscle force-velocity relationship was applied to empirical elbow-torque curves to correct for variable velocity during acceleration of an inertial load. The planned experiment will permit evaluation of this exponential force-velocity relationship.

2. Design Study of Prosthetic Elbow Flexion Using the BPA

Tests of the electro-pneumatic arm during this quarter have yielded velocity-flexion-time diagrams for the system with various loads at the terminal device. Inlet and exhaust orifices were adjusted to regulate flexion and extension velocities, and these were photographed on an oscilloscope screen. The displacement signal was electric, provided by a potentiometer mounted coaxially with the elbow; differentiation of this signal as described below yielded a velocity signal.

Lacking a suitable techometer, we resorted to a capacitance-resistance circuit for differentiating the displacement voltage to obtain velocity. Circuit parameters were calculated to minimize error in the frequency range from one-tenth to one cycle per second, and a low-pass filter (short-time integration) was applied to the displacement signal to minimize the noise characteristic of this type of electrical differentiation. The circuit was tested in the given frequency range with sinusoidal and triangular inputs to give the results shown in Figure 8. In these derivatives it is apparent that the rise-time

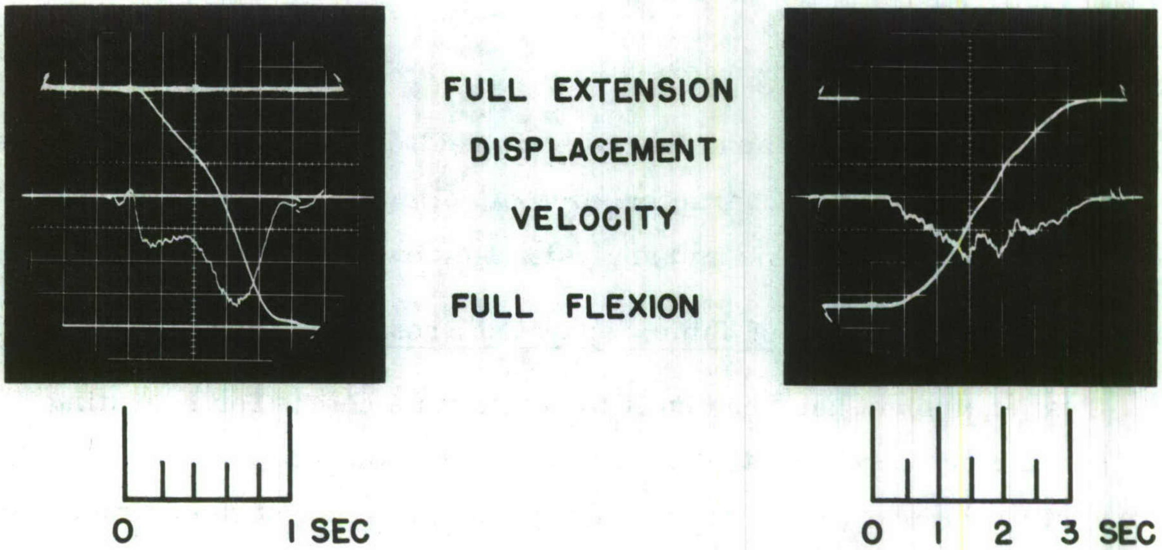


DIFFERENTIATION OF KNOWN FUNCTIONS

FIGURE 8

of the square wave which results from differentiating the triangular input is about two twenty-fifths of one cycle at one cps and negligible at one-tenth cps. Since phase shift at these frequencies is also low, we felt justified in using the method. The steps which occur in the low-frequency sine wave derivative are caused by small changes in slope in the input, which is synthesized from a series of straight-line segments.

Applying the method above to the electro-pneumatic arm tests, we found that velocity was highly variable during both flexion and extension at low velocities, but more constant at higher flexion rates. (Gravitational acceleration is insufficient to produce high velocities during extension.) The oscillographs of Figure 9 show that when the arm flexes from full extension to full flexion in one second (130 degrees in one second or an average velocity of about two radians per second), the velocity goes through one inflection at ninety degrees. This inflection is partly due to the fact that the load starts to decrease at this point, and partly to the fact that the variable-ratio pulley



ELECTRO-PNEUMATIC ARM DISPLACEMENT-VELOCITY-TIME FUNCTIONS

FIGURE 9

which is used to couple the actuator to the forearm is a three-arc approximation of the theoretical shape. In the slower extension curve it appears that this inflection excites the spring-mass system of actuator air and forearm to undergo damped vibrations at a frequency of about three-halves cycle per second. Braid friction in the actuator is the principal damping force, and it is obviously insufficient.

In addition to a closer match between the actuator and load, more damping is indicated as necessary to reduce the observed vibrations. This damping could be provided at low cost by a double-acting piston having different programmed damping coefficients for flexion and extension. This addition would have the further merit of protecting amputees from dangerously high flexion or extension velocities in case of control system failure or misuse. The newly-designed velocity transducer described below will be used in future tests to decrease the labor of data reduction.

3. Bellows as Elbow Flexors

Using the test equipment described in Section IV. A. 3., tests will be run to determine operating characteristics of bellows. Data from these tests will be used in synthesis and analysis of elbow flexion systems.

B. Sequential Analysis of Time-Separated Prosthesis Control Functions

Test equipment has been built to obtain time charts for operating cycles of the electro-pneumatic arm and for body-powered prostheses. Data for converting the previously-reported sequence diagram of the former into a time chart appeared as pips superposed on the displacement curve of arm motion in a time base. The plan for body-powered prostheses is discussed under IV. A. 3.

Plans for Next Quarter

Actions as indicated above.

C. Socket Fit Studies

No reportable progress.

Plans for Next Quarter

1. The photoelastic research will be completed.

2. A firm, the Clark Electronic Laboratories, has been found that produces a pressure-sensitive paint. This paint comes in various types differing in their range of sensitivity. Also, they manufacture sub-micro pressure transducers, 1/64 in. thick, capable of measuring from .001 psi to 50 psi. By applying the paint to the transducers, it should be possible to measure the actual pressure produced on various parts of the stump by the prosthesis, as the dimension of the sensitive element is so small that it will not interfere with the fitting. Preliminary measurements will be taken on selected amputees.

III. SELECTED PROSTHESIS APPLICATION STUDIES

Sponsor: U. S. Veterans Administration

A. Double Pectoral Tunnel Cineplasty

The one known amputee subject is still not available for tests. His pectoral muscle has weakened from lack of use and several weeks of exercise will be required prior to testing. When he becomes available he probably will serve additionally as a subject for bioelectric studies.

B. Prostheses for the Severely Handicapped

Following modification of the electro-pneumatic arm amputee trials will be conducted in the laboratory as outlined in the March 1961 progress report. These trials will possibly be run concurrently with bioelectric studies during August and September. In view of the deficiencies found in velocity characteristics of the arm, with their effect on the operating time chart, the amputee experiment for its evaluation has not yet been designed.

Much material is being added to the report on body-powered prostheses, which is now expected to be completed by September 1961.

Plans for Next Quarter

Continuation of work in progress.

IV. SENSORY MOTOR FEEDBACK INVESTIGATIONS

Sponsor: U. S. Veterans Administration

A. Control Engineering "State of the Art" Surveys

Additional material has been gathered for this survey throughout the past year. During the coming year, we anticipate publication of a series of technical notes in which we will attempt to delineate characteristics and limitations of presently available components. We do not envision compilation of an exhaustive index or catalog, since such a listing would necessarily be obsolete at birth.

1. Evaluation of the Braided Pneumatic Actuator

The most important areas not yet covered in this project have been investigated by Schulte.[1] The analysis is thus considered completed. Plans for publication have been made.

Plans for Next Quarter

Conclusion of this project and publication of findings.

2. Evaluation of Existing Externally Powered Prostheses

Progress on this project was impeded by the loss of competent and experienced help. As a subproject, however, the elbow locking mechanism of the Heidelberg arm was analyzed and redesigned (see Sr. Projects).

Plans for Next Quarter

Resumption of work, manpower permitting.

3. System Analysis of Existing Prostheses

In order to carry out the aims of this project, time test stands with their necessary controls, circuits and measurement transducers were designed and are close to completion.

Figure 10 shows the individual characteristics of the test stand which will be used to determine diagrams of prostheses. A complete description

of the test stand and characteristics of the specially designed force transducer shown in Figure 11 will appear in Biotechnology Laboratory Technical Note No. 18, "Prosthesis and Actuator Test Equipment".

The actuator test stand with the specially designed velocity transducer, shown in Figure 12, will be similarly described in Technical Note No. 18.

Plans for Next Quarter

Completion of test stand construction and testing. Calibration of measuring transducers.

B. Methods Development and Special Design Investigations

1. Investigation of Magnetic Muscle Force Transducers

The use of sensitive bourdon tubes in the imbedded unit was investigated. Technical difficulties have, until now, prevented successful construction of a plastic unit.

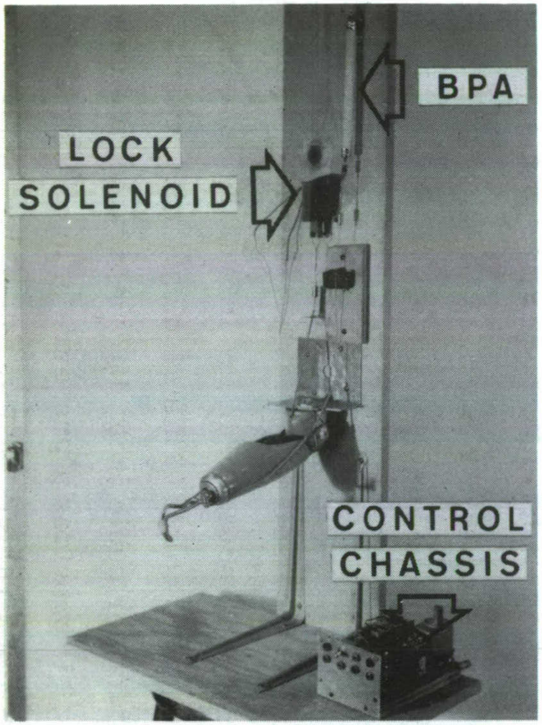
Plans for Next Quarter

Continuation of efforts with a plastic unit.

2. "Meet the Load" Elbow Lock

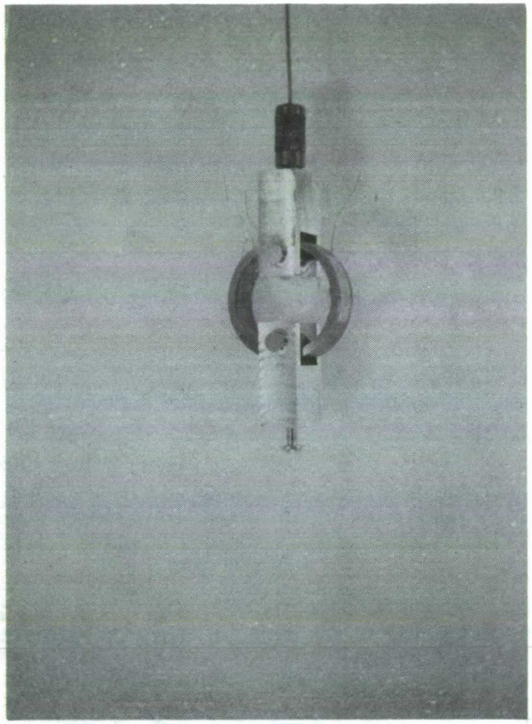
Work on this investigation is reported in Sections II. A. 2, II. B, and III. B. Periodical and catalog searches have disclosed miniature components, valves excepted, which could be used with a transistor-powered logic and control circuit small enough to be mounted in the humeral section or forearm shell.

The valve problem may be solved by using a bistable pneumatic element which has been recently reported in the literature as an experimental development for logic circuits. This element, with potential packing density of 2000 to 6000 units per cubic inch, is comparable in size with electronic micromodules. It provides a pressure gain of 100, so that control could be effected through a variety of miniature electronic devices.



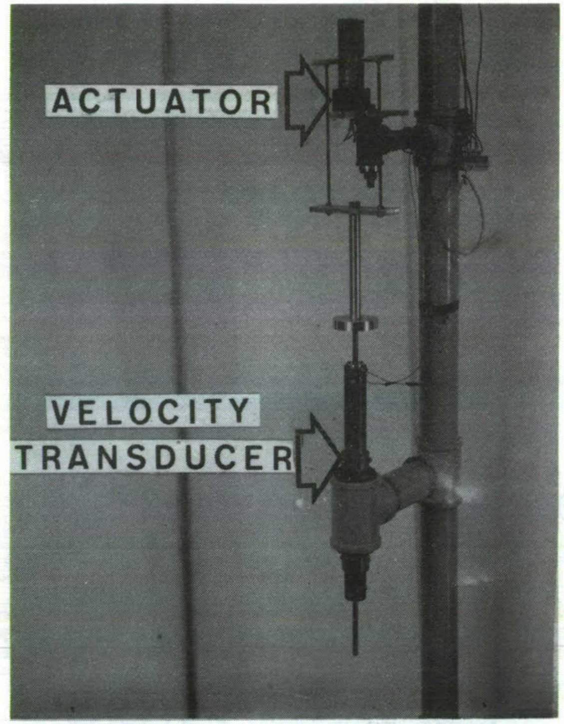
SYSTEMS TEST STAND

FIGURE 10



FORCE TRANSDUCER

FIGURE 11



ACTUATOR TEST STAND
WITH VELOCITY
TRANSDUCER

FIGURE 12

Its use would require modification of the arm control circuit to substitute pneumatic actuators for the solenoids now used for operation of the main valves. Since its standby flow is very small, it might also be practical for use in a protective circuit to avoid the possibility of inadvertent rapid flexion which has been previously reported.

Plans for Next Quarter

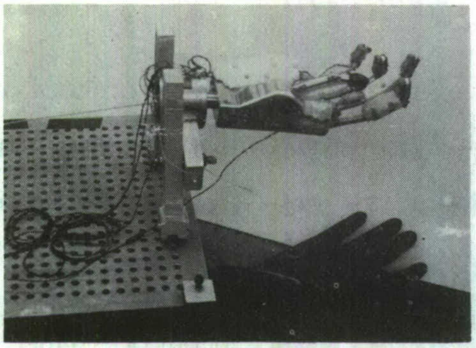
Design, fabrication, and trial of an accurate variable-ratio coupling and/or a damping device for elbow flexion.

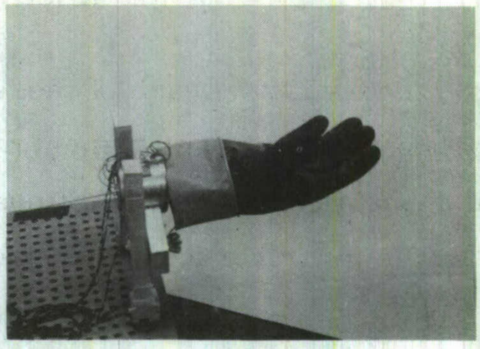
A technical report on this design investigation is in press and should be published by September 1961.

3. Feasibility Studies of a "Reflex-Controlled" Electromechanical Hand

The construction of a working bench model of the hand has been completed. Some experiments were carried out and a film of the dynamical response of the hand was taken. Briefly, the mechanical part of the hand is composed of a hollow body connected on one side to the wrist joint and on the opposite side to the fingers. The wrist joint is built around a ball bearing, four springs maintaining the hand in its normal position relative to the forearm and at the same time allowing a limited freedom to oscillate. The fingers are made of hinged sections that have one degree of freedom. Individual finger cables are connected through springs to a main cable. The thumb has a cable by itself. The fingers are normally in a stretched position, the pull on the cable producing their bending. The two cables are connected to the central shaft of a positioning servomotor forming an angle α between them. This angular displacement produces a delay in the speed of bending of the thumb relative to the other fingers according to the direction of rotation of the shaft of the servomotor.

Pressure sensitive transducers are distributed in various parts of the fingers, the body of the hand, and inside the wrist joint. Through simple electrical connections, a division of the hand into zones is achieved: zone one being the fingers; zone two the palm of the hand; and zone three, the wrist.



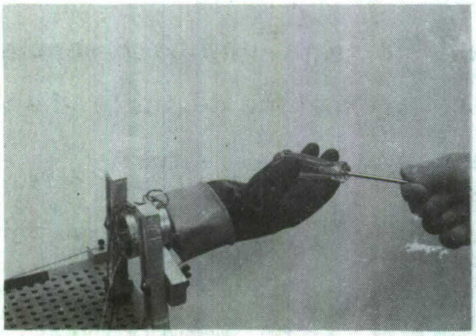


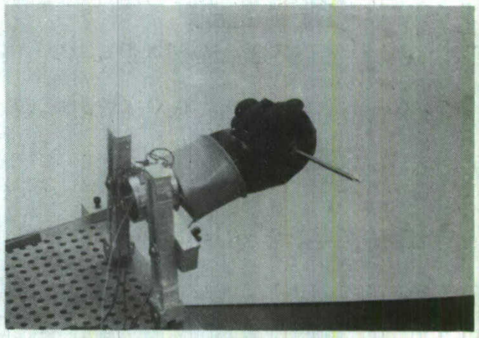
THE HAND WITHOUT THE GLOVE

FIGURE 13

THE HAND WITH A GLOVE

FIGURE 14

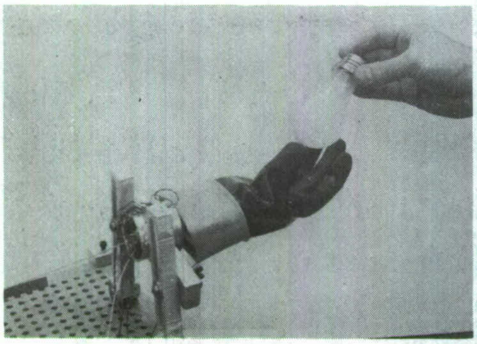


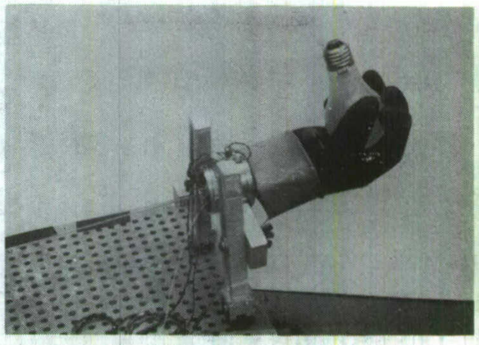


THE HAND GRASPING A SCREWDRIVER

FIGURE 15

FIGURE 16

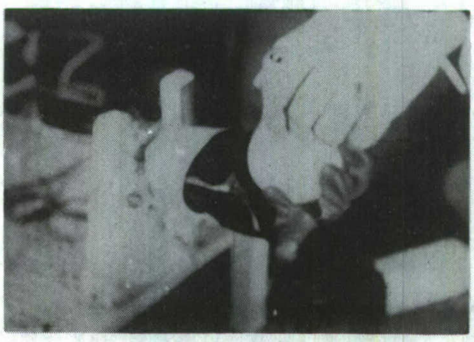




THE HAND GRASPING A LAMP

FIGURE 17

FIGURE 18



FRAME FROM A FILM ON THE DYNAMIC RESPONSE
OF THE ELECTROMECHANICAL HAND

FIGURE 19

The signals derived from each of these zones are fed to the servomotor to produce either a grasping movement or a pinching movement according to the origin of the signal. Two additional transducers, one in the wrist and the other in the ulnar border of the palm, provide the signal for opening the hand.

The results so far obtained can be summarized as follows:

1) Use of a positive feedback loop to relieve the amputee of controlling directly some basic functions of his artificial hand seems feasible. Such a hand does not require any locking device and seems to be in accord with the prosthetic principle of least effort.

2) The mapping of elective zones of sensitivity in the hand corresponding to specific functions may lead to important new developments.

3) The mechanical delay in the relative speed of bending the thumb and the other fingers, although realized in a very simple way, makes it quite difficult to differentiate automatically between the grasping and the pinching movements.

4) The special construction of the wrist joint with its sensitive pads, acting like an electromechanical scale, affords a simple way to adapt the grasping force of the hand to the weight of the object lifted.

Plans for Next Quarter

Publication of an article covering the developmental phases of the hand.

No further work is anticipated during the next quarter.

Proposed direction of further investigations should include:

1. Evaluation of other types of transducers (see also B-2).

2. Exploration of the possibility of utilizing multi-layered sensitive elements with different thresholds of sensitivity.

3. Evaluation of the principle of zonal division of the hand with some corresponding function.

4. Evaluation of various types of feedbacks.

REFERENCE

1. H. F. Schulte, Jr., "The Characteristics of the McKibben Artificial Muscle", Appendix H of "The Application of External Power in Prosthetics and Orthotics," National Academy of Sciences, National Research Council Publication, (74), Washington D. C. 1961.

V. PHYSIOLOGICAL MEASUREMENTS OF HUMAN THERMAL TOLERANCE

Sponsor: U. S. Air Force

Water loss from the isolated arm was measured on two subjects for various conditions of the air surrounding the subject and the arm. Water loss rate is shown in Figure 20 as a function of room temperature and of temperature within the arm chamber. Of twenty-two attempted runs, three were lost at some point during their course due to equipment malfunction. Four others were excluded because of recorded evidence that heat exchanger temperature was below the collector temperature at least during a part of the run, which permitted the possibility of incomplete collection. Examination of the data could not account for the large amount of water collected in runs 10 and 11 on subject KG, and these data are included in the graph.

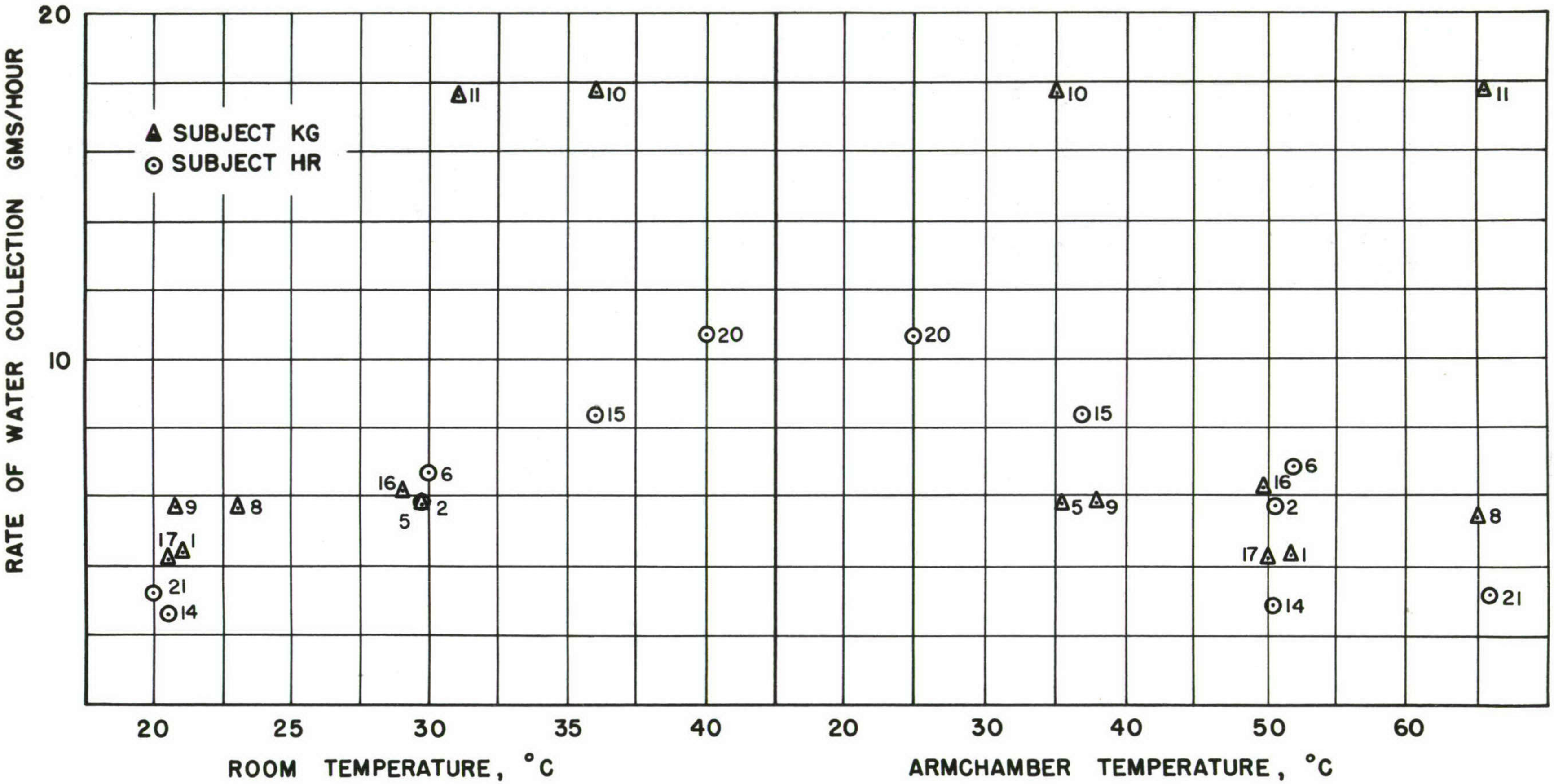
As can be seen from the graph, the remaining points are grouped fairly closely at the lower room temperatures, at which sweating is not expected. Plotting water loss as a function of arm chamber temperature leads to slightly more scatter.

Owing in part to the loss of experiments, a complete test of the relation between peripheral and central control of sweating was not made; for this, experimental runs with both arm and body, cold or hot, are necessary. Plans for pursuing this are included in the next section.

The head chamber, constructed as a lab project by a graduating senior student, has been tested and found to be quite satisfactory.

Plans for Next Quarter

Full time work during the summer by personnel participating in the project is expected to substantially increase the rate of progress. Experiments on additional subjects will be conducted to complete the arm water loss experiment. Additional equipment, such as temperature controls and a vortex tube for isolating the head chamber from the room environment, will be designed and fabricated concurrently in order to minimize the time required for changeover.



WATER LOSS AS FUNCTION OF
AMBIENT TEMPERATURE

FIGURE 20

VI. CONSTRUCTION OF A HIGH TRANSIENT RATE ENVIRONMENTAL CHAMBER

Sponsor: U. S. Air Force

An alternative approach to the design of a chamber heated by circulating fluid was explored by F. C. DeBiasio and R. W. Allen as a semester project for the course " Principles of Engineering Investment and Economy" . Results of this study suggested the possibility of constructing the chamber walls from aluminum tube-sheet by a process currently used to form the freezing compartments of home refrigerators.

A cost equation containing those factors in the design which are subject to optimization was derived in a form which can be programmed for the Bendix G-15 digital computer available within the department.

Plans for Next Quarter

Depending upon the availability of personnel, who are engaged presently in the arm chamber runs, the economic optimization described above may be pursued.

VII. DEVELOPMENT OF A RATIONALE FOR PSYCHOMOTOR TESTS MEASURING PERFORMANCE DECREMENTS IN EXTREME ENVIRONMENTS

Sponsor: U. S. Air Force

The first draft of a technical report is in preparation.

Plans for Next Quarter

Publication of a technical report.

VIII. EFFECTIVENESS OF ELIMINATION OF DISPLAYED INFORMATION WITH OBSERVER PRACTICE INCREASE

Sponsor: U. S. Navy

A. Interaction of Display Redundancy and Display Complexity During Training

B. Determination of a Hierarchy of "Perceptual Usefulness" of Geometrical Cues in a Dial Reading Task

A final summary report is in preparation.

Plans for Next Quarter

Future work wil depend upon the award of a contract renewal.

IX. RESEARCH ON THE PERFORMANCE OF HUMAN OPERATIONS OF TRACKING INSTRUMENTS

Sponsor: U. S. Navy

A. Accomplishments 1960-1961

The work during 1960-1961 was conducted in four phases, each dealing with different aspects of the total problem. In addition, design modifications were made on the missile and satellite tracking simulator on long term loan from China Lake Naval Ordnance Test Station in order to increase its versatility, reliability, and utility for formal studies of human tracking under "quasi-real" conditions. The four phases of investigation were:

Phase 1 Investigation of design specifications that will facilitate optimum human performance in a particular tracking situation.

Phase 2 Exploratory activity, including bibliographic research, to advance the state of the art and to plan an integrated program.

Phase 3 Investigation of tracking performance under actual field conditions.

Phase 4 Equipment maintenance and systems improvement.

The specific activities in each of these phases are summarized below:

Phase 1

(A) Two experiments were performed to study the effects of variation in amplitude of controller motion and controller spring tension. Two different handlebar controllers were also compared.

Preparation is being made for experimental work to investigate the effect of variations in display modes on tracking performance. The specific variables to be evaluated are:

(1) The effect of the field of view

(2) The effect of error magnification

(3) The effect of TV tracking independently of proprioceptive cues

(4) The effect of proprioceptive cues

(5) The feasibility of providing two fields of view and switching between them.

(6) The interaction of the above factors with trajectory complexity.

Phase 2

(A) Two conferences were held at the University of California Arrowhead Conference Center with representatives of several missile and aircraft test ranges to exchange information on problems of missile and satellite tracking.

(B) Extensive literature reviews are being made to yield necessary background information and provide an understanding of humans in tracking situations:

(1) A review on the effects of error magnification and field of view is in progress. In general, there is little or no data directly bearing on the problems of tracking with optical devices. However, sufficient relevant information is available to indicate directions of experimentation. Specifically:

(a) Error magnification appears to be most easily employed in a compensatory display. However, error magnification only improves performance for low frequency trajectories. For higher frequencies pursuit tracking is superior to magnified compensatory tracking. This fact lends strength to the idea that a dual optical system should be available to tracking operators, a high magnification system for steady courses and a large field low magnification system for erratic, high frequency courses.

(b) Proprioceptive cues will add a pursuit component to the tracking task and therefore should improve performance. The possibility of confusion between visual and proprioceptive cues is under study.

(c) Little data is available on field of view.

(d) The important variables in considering the relation between display design and performance are the effects on the retina of the observer, e. g., retinal velocity of the target and retinal size. Experimental results should be stated in these terms.

(e) Because of the wide range of trajectories encountered in tracking, it may be necessary to specify more than one optimum display control configuration.

(f) A significant theoretical problem consists of relating the concepts of prediction, velocity discrimination, and distance discrimination to the variables presently being studied, i.e., field of view, trajectory, training, and error magnification.

(2) A review of the relation between eye movements and visual displays is in preparation. This review is in anticipation of using the Mackworth eye movement camera which is being procured for tracking studies.

(C) Theoretical and experimental work has been conducted on a sampled-data servomodel for human operator behavior. Results to date indicate that such a representation may be of significant value for specifying design parameters on tracking instruments.

<u>Phase 3</u>

The experimental trackers worked in the field at NOTS during the summer of 1960. The experience of these trackers has helped to indicate both equipment handling difficulties and procedural problems.

<u>Phase 4</u>

<u>Equipment Maintenance and Systems Improvement</u>

(A) Direct Modification of Hardware

(1) Recording circuits. Facilities are now available for recording

the following variables in an analog form on magnetic tape:

(a) Tracking error, both azimuth and elevation

(b) One of the following at any one time

(aa) Controller position, azimuth, and elevation

(ab) Mount position, azimuth, and elevation

(ac) Mount velocity azimuth, and elevation

(2) An audio system was installed for recording voice comments on the magnetic tape.

(3) The DC amplifiers have been modified to reduce drift.

(4) A displacement aiding circuit has been designed which provides a greater displacement component with a longer rise time.

(5) The target trajectory device has been modified to cover a larger area of the quartersphere and to increase its stability.

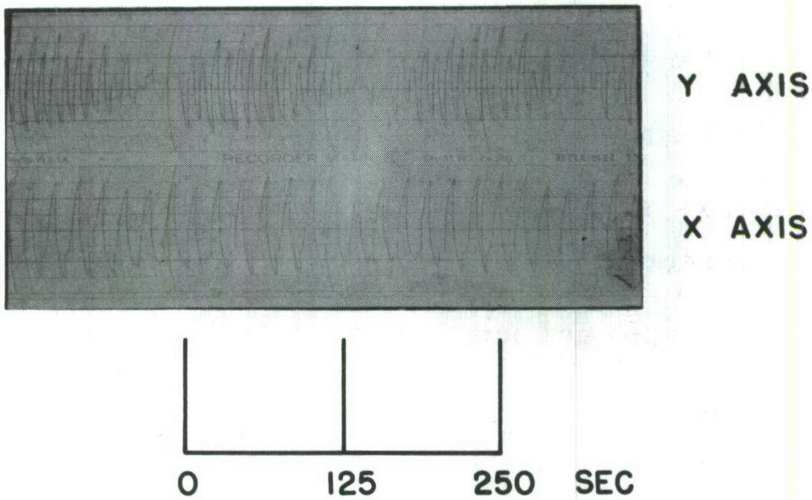
(6) A closed circuit TV system has been installed for tracking with a TV display. Provision will be made to mount the TV monitor on the tracking mount.

(7) The optical sighting system has been modified to allow variation of the field of view.

(8) Plans are in progress to install a zoom lens on the TV pickup and to couple the lens magnification to the tracking error.

A compact-sized function generator has been designed and built to provide one- or two-dimensional inputs for tracking tasks. It synthesizes complex waveforms having periods several minutes long, mixing two or more low frequency oscillations and their second harmonics in variable relative amplitudes. The complex waveform and long period make the functions essentially nonlearnable, so that subjects experience apparently random forcing functions. One of the shorter periods is shown in Figure 21. Functions having repeat cycles

more than fifteen minutes long have been produced with only two frequencies and their harmonics.



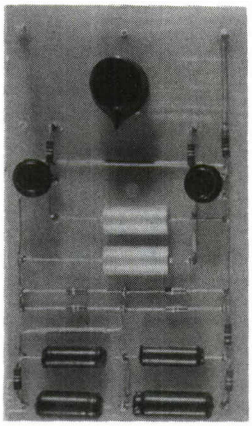
SHORT FUNCTION CYCLE

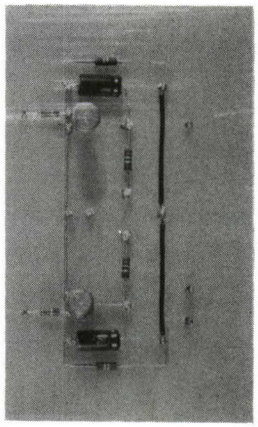
FIGURE 21

Oscillations are produced by transistor multivibrators having good frequency and amplitude stability, with frequency continuously variable from 0.04 to 0.07 cycles per second. The two half cycles of the squarewave output are summed and shaped to produce the second harmonic, and both the fundamental and harmonic are passed through filters which smooth them but leave a high harmonic content. The various frequency components are then summed into a short-period integrator which eliminates higher order harmonics which would give discontinuous effects in acceleration and velocity. Sine-wave oscillations could be used, but the harmonic content of the partially-smoothed square waves reduces the number of frequencies required to produce a complex waveform.

A two-frequency unit with provision for two-dimensional output was assembled on a three-by-five-inch circuit card, but for flexibility

and ease in assembly, the individual circuits (oscillators, mixers, and integrators) of a three-frequency unit have been built on individual cards. An oscillator and integrator are shown in Figure 22.





MULTIVIBRATOR INTEGRATOR

COMPACT FUNCTION GENERATOR
FIGURE 22

(B) Projected work for 1961-62

(1) Equipment Improvements and Modifications

(a) Direct Modifications

(aa) Coupling a Zoomar Lens with the error signal.

(ab) Investigation of a more flexible trajectory programming system.

(ac) Design of an improved displacement and acceleration aiding circuit.

(ad) Other changes as the experimental program dictates.

(2) Data Reduction

(a) Work out details of efficient system for handling statistical analysis of experimental data.

(b) Investigate transforms of data to yield maximum information about tracked object.

(C) Experimental Program

(1) Simulator Experiments

It is expected that the data analysis for the current experimental program described above will extend into the next fiscal year. The display configurations under study should lead to further directions of research. These may include:

(a) The effect of target contrast for both optical and TV viewing.

(b) Study the effect of field of view and magnification over a wider range than possible with the present equipment.

(c) Study the usefulness of coupling a Zoomar Lens to the tracking error as a solution to the acquisition problem.

(d) Analyze the interaction of the controller and computer aiding functions with the display mode.

(2) Multi-Man Tracking

The initial experimental work will investigate three two-man team configurations. Team performance will be compared with individual performance for variations in input frequency and system dynamics. Because little background is available in this area, it is planned to progress by a series of relatively small experiments in order to follow the most promising leads. Additional work is contemplated on the effect of team position of good and poor trackers, the effect of a knowledge of the team situation by each tracker and the effect of presenting each tracker with different components of the input signal.

(3) Problem Studies

(a) Conduct critical incident evaluations of tracking problems. The results of these studies will be used to recommend

procedural and equipment changes.

(b) Conduct vigilance studies of the effects of countdown interruptions and irregular waiting periods on operator performance.

(D) Theoretical Studies Program

(1) Analysis of Human Operator Properties

(a) Continue theoretical studies of operator data processing.

(b) Initiate detailed planning and inplementation for experimental verification and evaluation of mathematical representation of human operator characteristics.

(2) Literature Review

Continue to review pertinent areas to integrate and direct current work.

<u>Plans for Next Quarter</u>

1. Field of view experiments on tracking research simulator

2. Preliminary multi-man tracking experiments

3. Continuation of bibliographic work

X. ACADEMIC AND STUDENT ACTIVITIES AND PROJECTS

Engineering 299 Projects (Graduate Credit), Spring Semester 1961

Hegenwald, James:	Mechanical Shock
Hendrix, C. E.:	Transformation of Bioelectric Signals
Osman, O. B.:	Instrumentation for Variable Field TV Tracking
Watler, J. F.:	Bio-Engineering Controls in Aircraft
Weltman, Gershon:	Multi-Man Tracking System

Engineering 199 Projects (Undergraduate Credit), Spring Semester 1961

Baskevitch, Eugene:	Phase Measurement Techniques
Cressler, C. S.:	Survey of Literature on Guidance Devices for the Blind
Roe, Arnold:	A Critical Look at the Field of Biotechnology

Engineering 104D Projects (Senior Students), Spring Semester 1961

Dr. Lyman in Charge:

Thomas B. Henry:	Economic and Learning Evaluation of TV as a Classroom Teaching Aid
Ernest J. Selzer:	Multi-Parameter Head Chamber for Ventilation and Heat Loss Research
Martin S. Tatch:	Instrumentation of a Time-on-Target Indicator for the Human Tracking Project.

Dr. Paskusz in Charge:

Amotz Frenkel:	Evaluation of Powered Arm Prosthesis
Michael D. Furst:	Large Area Sound Source
Mirko Najman:	Analog of the Human Inner Ear

XI. PROFESSIONAL ACTIVITIES OF STAFF MEMBERS

April 21 and 22:

Dr. John Lyman and Mr. George Bekey, a Ph. D. candidate in the Department of Engineering, attended the Symposium on Biomedical Electronics held at the El Cortez Hotel in San Diego, California. Mr. Bekey read a paper SAMPLED-DATA MODELS OF THE HUMAN OPERATOR by Bekey and Lyman.

May 11, 12, 13:

Dr. Paskusz attended the 61st meeting of the Acoustical Society of America in Philadelphia, Pennsylvania; his paper, AN EQUIVALENT CIRCUIT STUDY OF FENESTRATION, was read at the meeting.

ABSTRACT

Advances in operative techniques are usually achieved by experimental methods. This paper describes an attempt, through use of an equivalent circuit, to evaluate the effect of parameter variation in the fenestration operation. Results predict a 30 db improvement over the usual fenestrated hearing acuity through most of the speech spectrum.

May 22:

The Second Conference on Problems of Missile and Satellite Tracking was held at the University conference grounds, Lake Arrowhead, California. Representing the Biotechnology Laboratory were Dr. Groth, Dr. Lyman, and Mr. Kenneth Ziedman.

June 1 and 2:

Dr. Lyman attended the 9th annual Human Engineering Conference held in St. Louis, Missouri at the McDonnell Aircraft Corporation.

Mr. Gerald Gwynne has been named as Chairman of the Basic Sciences Division of the Los Angeles Section, A. I. E. E., for 1961-62.

June 6:

Dr. G. F. Paskusz attended the first Annual Symposium on Human Factors Research, jointly sponsored by Human Factors Society of Southern California and Los Angeles State College, held on the LASC Campus.

June 14-17:

Dr. Hilde Groth attended the annual meeting of the Western Psychological Association in Seattle, Washington and presented a paper (J. Lyman-Co-author): Changes in Perceptual "Cue Utility" at Various Stages of Training on Two Dial Reading Tasks.

XII. PUBLICATIONS

H. Groth

"A Survey of Research Activities in Western Europe for Selected Areas of Biotechnology", UCLA Engineering Department Report No. 61-30

G. Paskusz and G. Gwynne

"Braided Pneumatic Actuator: Dynamic Test Results and Extension of Previous Analysis", UCLA Engineering Department Report No. 61-36.

Summary: This report introduces results of dynamic tests of the Braided Pneumatic Actuator force-length characteristic and extends previous analysis to evolve design criteria for its use.

In the dynamic tests, actuator contractions under various loads were recorded both as functions of time and of force during contraction and extension, with air supply pressure as a parameter. Results of these tests are compared with theoretical results based on previous analysis. The theory is extended to include two possible means of increasing thermodynamic efficiency.

H. Groth and J. Lyman

"Exploring Training Methods for Dissociating Muscle Activity in Arm Prosthesis Control Applications," Perceptual and Motor Skills, in Press.

Summary: To evaluate the development of voluntary control over contraction of a selected muscle, two monkeys were subjected to surgery and studied over a twelve month period.

H. Groth and J. Lyman

"Evaluation of Control Problems in Externally Powered Prostheses," Prosthetics Appl. Journal, in Press.

H. Groth and J. Lyman

"A Hierarchy of 'Perceptual Usefulness' of Geometrical Cues in an Overlearned Dial Reading Task," Journal of Applied Psychology, in Press.

Summary: This study was designed to define a hierarchy of "perceptual usefulness" of geometrical cues in an overlearned dial reading task. The hypothesis was postulated that performance is a function of "perceptual usefulness of cues" rather than of the amount of information, redundancy and noise present in a given situation.

Examination booklets were prepared containing 24 pages with 12 "dials" of the same geometrical configuration on each page. A total number of 288 "dials" had to be read and recorded by each subject. For each page, 48 seconds were allotted for completion.

The task consisted of reading "clock-times" on these "dials". It was selected because it fulfilled the requirement of an overlearned task and also represented an acceptable laboratory abstraction of a dial reading task.

Eight cue configurations and three types of background were combined in a factorial design with 12 replications of different pointer settings for each of the 24 combinations. The test was administered individually in a treatment by subjects counterbalanced design. Twenty-one student subjects served in the experiment.

Results supported the hypothesis, and a rank order of "perceptual cue-utility" was found. The implications of the results for dial design have been discussed, and reliability and generality of the findings at various levels of training will be investigated in further studies.

David Garfinkle

"Some Field Experiences of Three Tracking Operators," Biotechnology Note; Engineering Department Report No. 61-34.

XIII. VISITORS TO THE LABORATORY

March 15:

Dr. Robert R. Reisz, Bell Telephone Laboratories, Murray Hill, New Jersey

March 16:

Professor Kenneth Hunt, Dean of Engineering, Monash University, Melbourne, Australia.

March 29:

Dr. Walter Goldberg, Instructor, Graduate School of Business Administration, Gothenburg, Sweden.

May 2:

Miss Isabelle Nel, Senior Lecturer in Education, University of Stellenbosch, Stellenbosch, South Africa (on fellowship from Wellesley College, Wellesley, Massachusetts).

May 10:

Mr. Sidney R. Stanley, Ordnance Leading Man -- A&E Test, and Mr. T. J. Kellums, Ordnance Mechanic, from the Naval Ordnance Test Station, China Lake, California.

May 17:

Dr. M. K. Fahnestock of the Physical Environment Unit, Mechanical Engineering Laboratory, University of Illinois, Urbana, Illinois.

May 24:

Dr. Harry Fisher of the Sandia Corporation, Albuquerque, New Mexico

June 1:

Dr. Robert Eason, Assistant Professor at San Diego State College and Research Psychologist with the Navy Electronics Laboratory, San Diego; and Dr. Joseph Sidowski, Associate Professor at San Diego State College.